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(54) SOLID-STATE IILUMINATION SYSTEM HAVING AN ARRAY OF LIGHT SHIELDS

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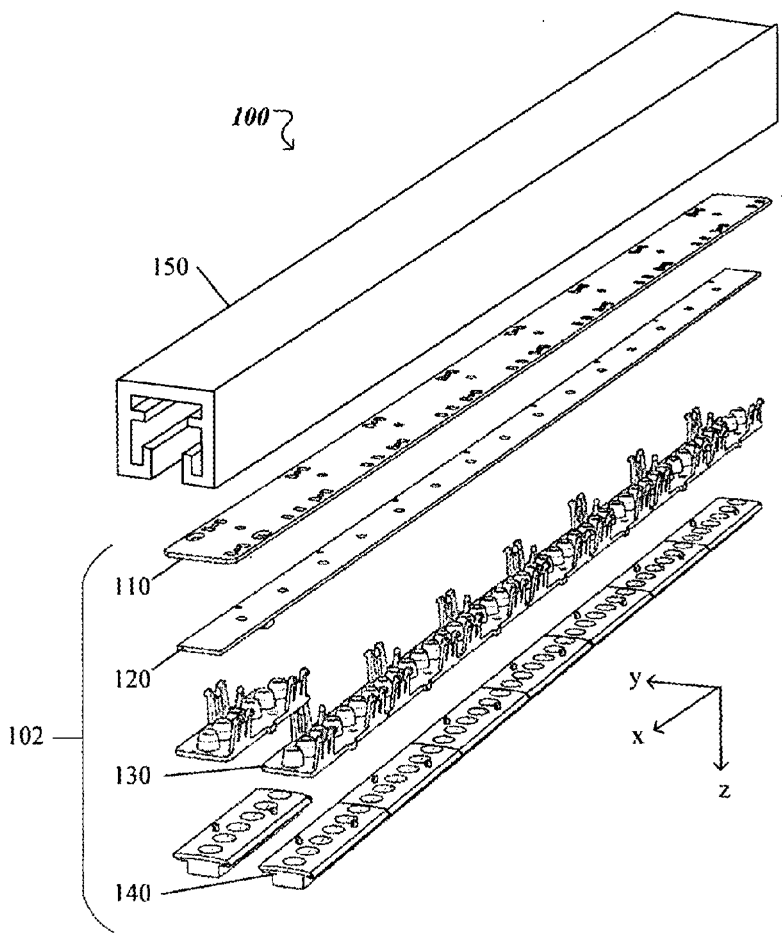
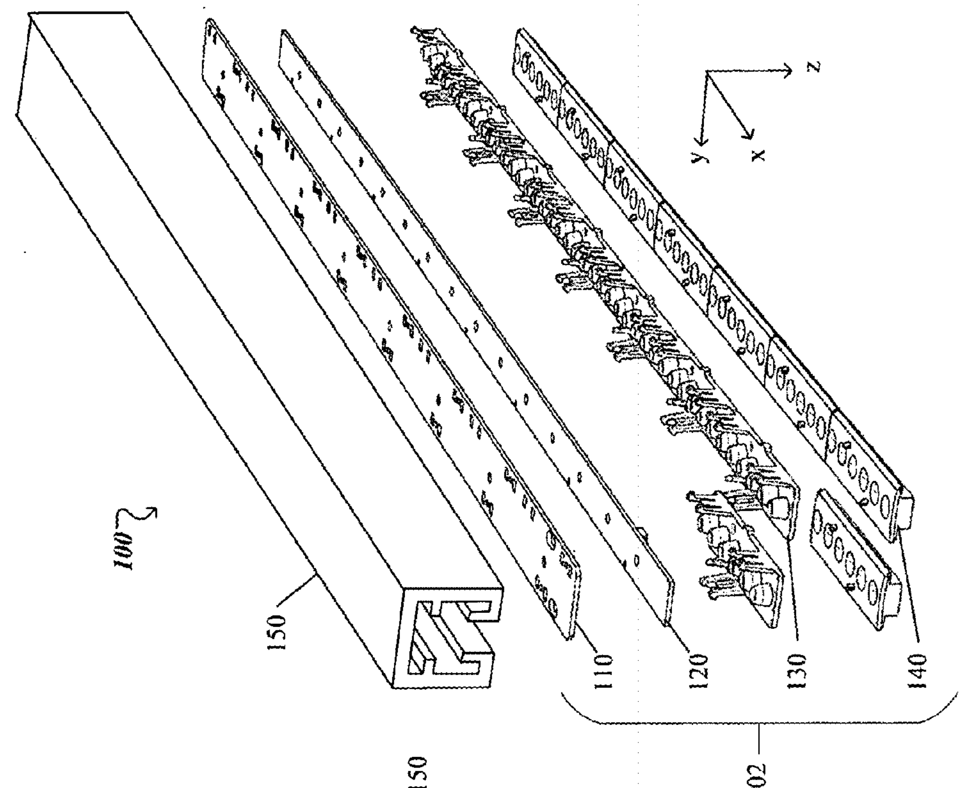
(52) **U.S. Cl.**
CPC ***F21K 9/69*** (2016.08); ***F21V 5/007*** (2013.01); ***F21V 11/16*** (2013.01); ***F21V 13/02*** (2013.01); ***F21V 21/34*** (2013.01); ***F21V 19/003*** (2013.01); *F21Y 2115/10* (2016.08)

(57) **ABSTRACT**

An illumination system includes a substrate; a one-dimensional (1D) array of light emitting diodes (LEDs) distributed on the substrate along a first direction; a 1D array of lenses optically coupled in one-to-one correspondence with the 1D array of LEDs; and a 1D array of light shields optically coupled in one-to-one correspondence with the 1D array of lenses, each light shield of the 1D array of light shields having an input aperture and an output aperture, the light shield comprising a lateral surface extending between the input aperture and the output aperture in a second direction substantially orthogonal to the first direction.




100
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102
y
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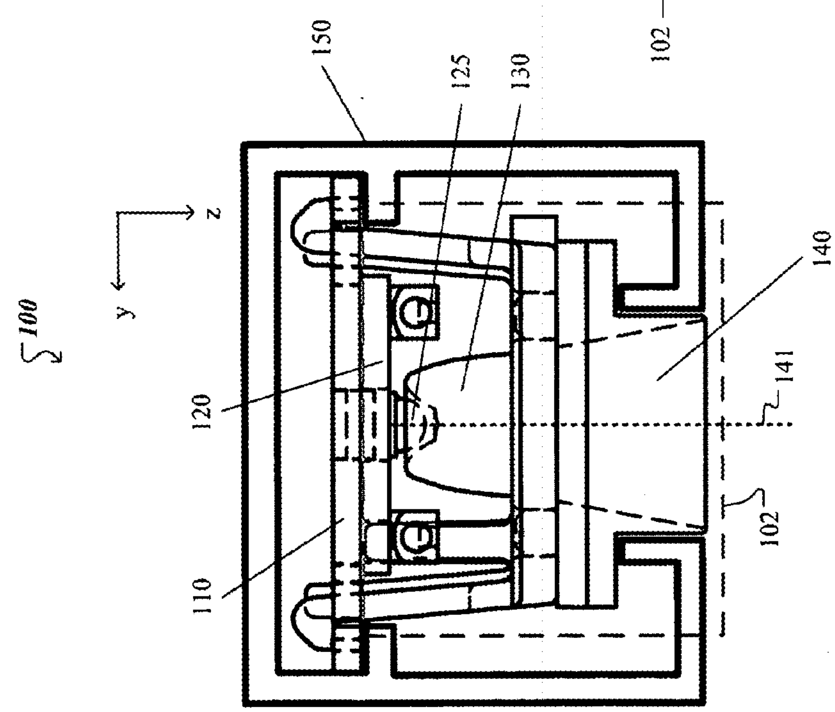
z

FIG. 1B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141
102

FIG. 1A

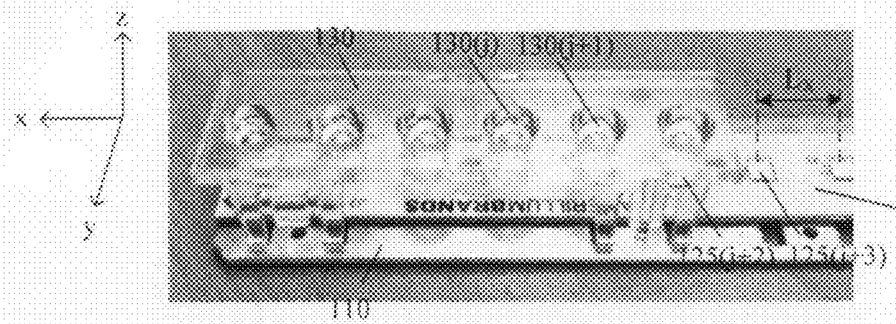
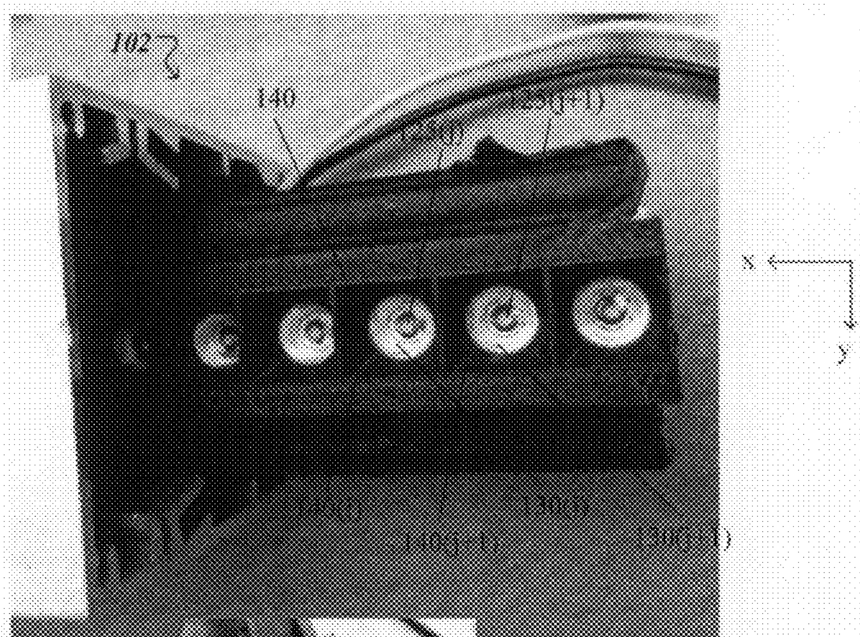


FIG. 1C

FIG. 1D



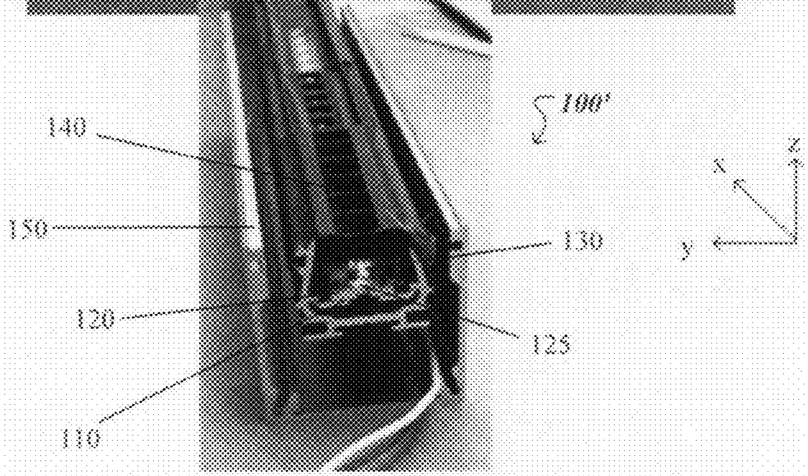


FIG. 1E

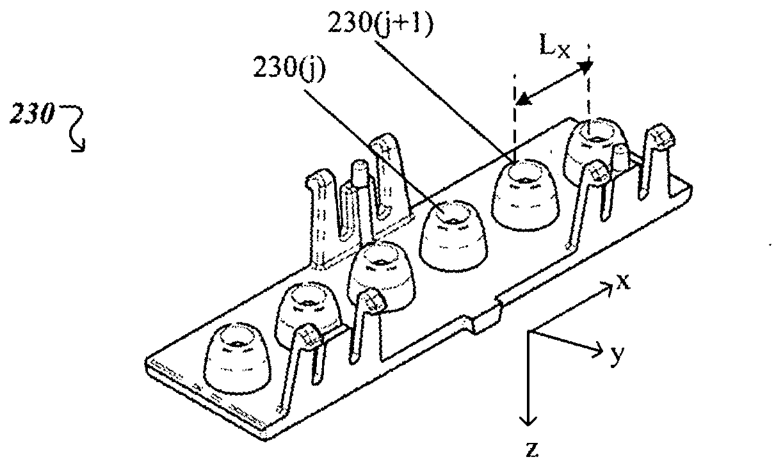


FIG. 2A

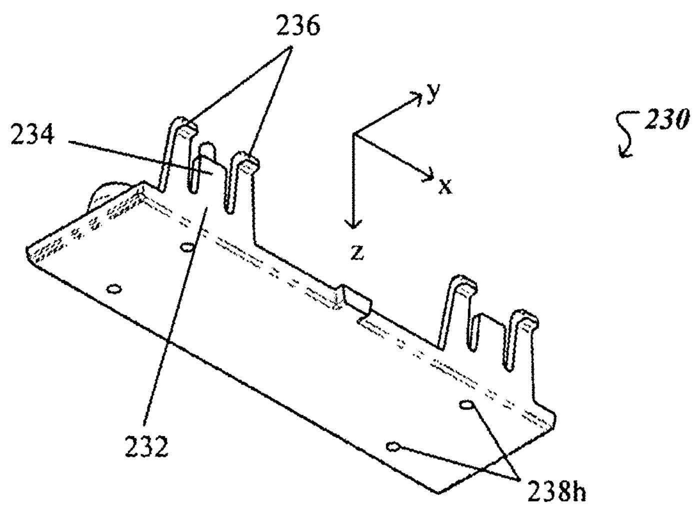


FIG. 2B

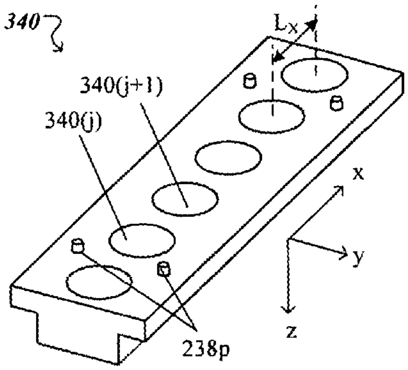


FIG. 3A

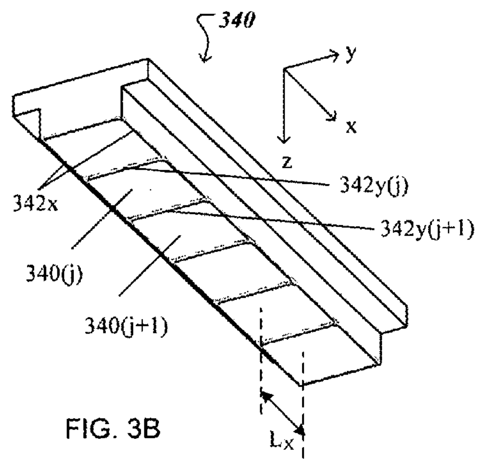


FIG. 3B

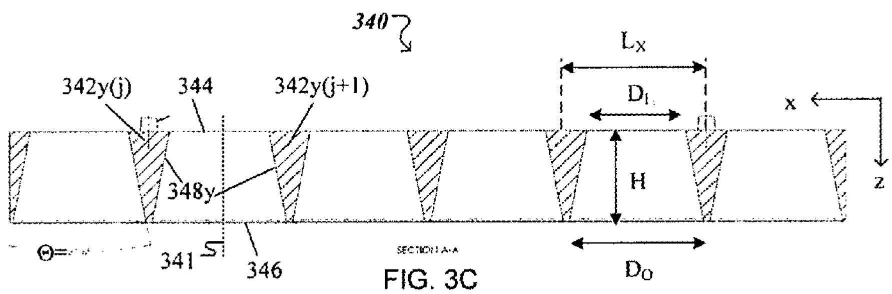


FIG. 3C

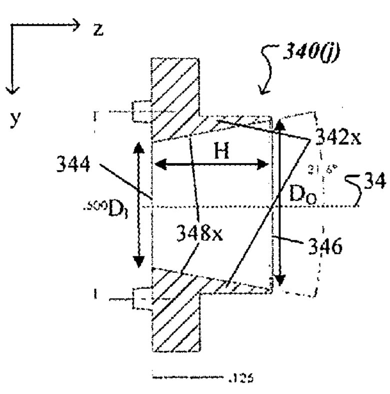


FIG. 3D

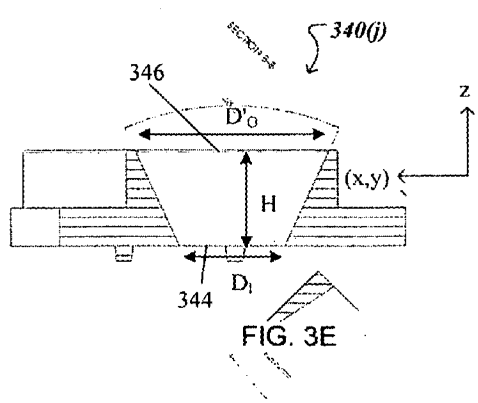


FIG. 3E

SOLID-STATE ILLUMINATION SYSTEM HAVING AN ARRAY OF LIGHT SHIELDS

FIELD OF THE TECHNOLOGY

[0001] The present technology relates generally to solid-state luminaires, and more specifically to illumination systems having an array of light emitting diodes (LEDs) and an array of light shields in one-to-one correspondence with the array of LEDs.

BACKGROUND

[0002] Many types of electric light sources, such as, incandescent lamps, fluorescent lamps, compact fluorescent lamps (CFL), cold cathode fluorescent lamps (CCFL), high-intensity discharge lamps have been used for general illumination purposes. The foregoing types of electric light sources are gradually being replaced in many general illumination applications by solid state light sources, e.g., light-emitting diodes (LEDs).

[0003] Development of LED-based illumination systems, e.g., LED-based pendant lighting fixtures or LED-based troffer lighting fixtures, has focused on ways to output as much of the light emitted by the LEDs as possible into the ambient while providing at least some directionality of propagation to the output light to make the latter safe and useful for general illumination purposes. For example, controlling glare of LED-based illumination systems and uniformity of illumination provided by LED-based illumination systems can be very challenging because the LEDs are quasi-point sources that emit very bright light. For instance, more recently, it has become desirable to reduce the size of apertures of the foregoing light fixtures, but still deliver the same light intensity (amount of lumens). This combination of requirements can have a potential negative affect on the comfort of people using such light fixtures. When the same amount of light is delivered from a small source, people tend to experience that source having more glare that others that use a larger aperture. Reduced aperture light fixtures, therefore, should exhibit a high degree of control of the light intensity distribution to prevent light from being emitted in the "glare region", which is above a 55-degree incident angle (which is measured from the horizon up). Optical elements, such as reflective plates and/or transmissive plates, are placed inside the LED-based illumination systems, in proximity to the LEDs, to redirect and mix the light emitted by the quasi-point source LEDs, so glare can be reduced and uniform illumination can be provided by the LED-based illumination systems.

SUMMARY

[0004] The present technology relates to illumination systems having an array of LEDs and an array of light shields in one-to-one correspondence with the array of LEDs.

[0005] According to a first aspect of the present technology, an illumination system includes a substrate; a one-dimensional (1D) array of light emitting diodes (LEDs) distributed on the substrate along a first direction; a 1D array of lenses optically coupled in one-to-one correspondence with the 1 D array of LEDs; and a 1D array of light shields optically coupled in one-to-one correspondence with the 1D array of lenses, each light shield of the 1D array of light shields having an input aperture and an output aperture, the light shield comprising a lateral surface extending between the input aperture and the output aperture in a second direction substantially orthogonal to the first direction.

[0006] Implementations of the first aspect may include one or more of the following features. In some implementations, the output aperture can be larger than the input aperture, and the light shield is arranged with the input aperture adjacent to a corresponding lens of the 1D array of lenses. Further, the lateral surface of the light shield can be a set of the lateral faces of a truncated pyramid, and a contour of the base of the truncated pyramid forms the output aperture. For example, the base of the pyramid can be a rectangle. Furthermore, the lateral surface of the light shield can be the lateral surface of a truncated cone, and a contour of the base of the truncated cone forms the output aperture. Additionally, the light shield can be configured in the following manner: the input aperture has a dimension D_I, the output aperture has a dimension D_O, and the input aperture and the output aperture are separated by a distance H along the second direction that satisfies the condition

$$\tan\frac{\theta}{2} \leq \frac{D_O - D_I}{2H}.$$

Here, θ is a divergence angle of light transmitted through the lens along the second direction. For example, the lens is shaped such that the divergence angle of the light transmitted through the lens along the second direction is less than 70°.

[0007] In some implementations, the input aperture can be circular. In some implementations, the 1D array of light shields can include a plastic material. For example, the plastic material includes PMMA.

[0008] In some implementations, each lens of the 1D array of lenses is a plano-concave lens. For instance, a surface of the lens adjacent to a corresponding LED is concave.

[0009] In some implementations, the 1D array of lenses can include a plastic material that is transparent to light emitted by the LEDs. For example, the plastic material includes PMMA.

[0010] In some implementations, the 1D array of LEDs can include six or more LEDs separated by a distance of about 0.5" between each other. In some implementations, the 1D array of lenses can be mounted on the substrate and supports the 1D array of light shields.

[0011] In some implementations, the illumination system can include a housing; and a mounting plate that supports the substrate. Here, the mounting plate is mounted inside the housing.

[0012] In accordance with the disclosed technologies, light that reaches the output aperture of each light shield advantageously incurs no losses as it propagates through the light shield. Additionally, the each light shield obstructs direct lines of sight to a corresponding lens for angles in the glare region, and, thus, inhabitants of rooms illuminated by the disclosed illumination fixtures, will perceive the illumination fixtures as glare free illumination fixtures.

[0013] The details of one or more implementations of the technologies described herein are set forth in the accompanying drawings and the description below. Other features, aspects, and advantages of the disclosed technologies will become apparent from the description, the drawings, and the claims.

BRIEF DESCRIPTION OF THE FIGURES

[0014] FIGS. **1**A-**1**B show an implementation of an illumination system having an array of LEDs and an array of light shields in one-to-one correspondence with the array of LEDs.

[0015] FIGS. **1**C-**1**D show aspects of optical components of an illumination system like the one illustrated in FIGS. **1**A-**1**B.

[0016] FIG. **1**E shows another implementation of an illumination system having an array of LEDs and an array of light shields in one-to-one correspondence with the array of LEDs.

[0017] FIGS. **2**A-**2**B show aspects of a lens array that can be used in the illumination systems illustrated in FIGS. **1**A-**1**B or FIG. **1**E.

[0018] FIGS. **3**A-**3**E show aspects of a light shield array that can be used in the illumination systems illustrated in FIGS. **1**A-**1**B or FIG. **1**E.

[0019] Like elements in different figures are identified with the same reference numeral.

DETAILED DESCRIPTION OF THE TECHNOLOGY

[0020] FIG. **1**A is a side view, FIG. **1**B is an exploded view and FIG. **1**E is a perspective view of illumination fixture **100**. The illumination fixture **100** includes illumination device **102** supported on a rail **150**. FIG. **1**D is a top view of the illumination device **102**. The illumination device **102** includes a mount **110**, a substrate **120**, a one-dimensional (1D) array of LEDs **125**, a 1D array of lenses **130** in one-to-one correspondence with the 1D array of LEDs, and a 1D array of light shields **140** (also referred to as an array of baffles) in one-to-one correspondence with the 1D array of lenses. FIG. **1**C (along with FIG. **1**A) shows that the lenses of the 1D array of LEDs **125** are separated from each other along a first direction (e.g., the x-axis) by a pitch Lx, and the 1D array of lenses **130** is optically coupled with the 1D array of LEDs. For example, the pitch Lx can be about 5 mm, 10 mm, 12 mm, 14 mm or other values. The substrate **120** is mounted on the mount **110** and supports the 1D array of lenses **125**. Additionally, the 1D array of lenses **125** supports the 1D array of light shields **140**, as shown in FIGS. **1**A and **1**E.

[0021] A light shield **140**(*j*) of the 1D array of light shields **140** has an input aperture and an output aperture larger than the input aperture, where j=1 . . . N, and N≥2 is the number of LEDs in the 1D arrays of LEDs **125**. The light shield **140**(*j*) includes a lateral surface extending between the input aperture and the output aperture. Note that an optical axis **141** of the illumination device **102** passes through respective centers of the input aperture and the output aperture and is disposed along a second direction (e.g., along the z-axis) orthogonal to the first direction. Moreover, the 1D array of light shields **140** is arranged relative to the 1D array of lenses **130** such that the input aperture of the light shield **140**(*j*) is adjacent to the corresponding lens **130**(*j*).

[0022] The input aperture of the light shield **140**(*j*) can be circular. In some implementations, the lateral surface of the light shield **140**(*j*) is a set of the lateral faces of a truncated pyramid, and a contour of the base of the truncated pyramid forms the output aperture. For example, the base of the pyramid can be a rectangle, such that the output aperture is a rectangular output aperture. In other implementations, the lateral surface of the light shield **140**(*j*) is the lateral surface of a truncated cone, and a contour of the base of the truncated cone forms the output aperture, such that the output aperture is a circular output aperture.

[0023] Light emitted by an LED **125**(*j*) along the second direction (e.g., along the z-axis) can have a Lambertian intensity distribution and an emission divergence θ_E, e.g., $\theta_E \approx 140°$. The corresponding lens **130**(*j*) that receives the emitted light from LED **125**(*j*) is shaped such that light transmitted through the lens along the second direction (e.g., along the z-axis) has a divergence θ that is smaller than the emission divergence θ_E. In some implementations, the shape of the lens **130**(*j*) can be such that an intensity distribution of the transmitted light is bat wing-shaped in polar coordinates. The corresponding light shield **140**(*j*) receives the light transmitted by the lens **130**(*j*) through the input aperture and allows the received light to directly propagate along the second direction (e.g., along the z-axis) to the output aperture without impinging on the side surface of the light shield. In this manner, light that reaches the output aperture of the light shield **140**(*j*) advantageously incurs no losses as it propagates through the light shield. Additionally, the light provided by the illumination device **102** through the output aperture of the light shield **140**(*j*) along the second direction (e.g., along the z-axis) has the same divergence θ as the light transmitted through the lens **130**(*j*). Moreover, the light shield **140**(*j*) obstructs direct lines of sight to the lens **130**(*j*) (or equivalently rays of light scattered by the lens) for angles in the range [θ/2,90°] relative to the z-axis, and, thus, an inhabitant of a room illuminated by the illumination fixture **100**, will perceive the illumination fixture as a glare free illumination fixture.

[0024] FIG. **2**A is a top perspective view and FIG. **2**B is a bottom perspective view of a 1 D array of lenses **230**. In some implementations, the 1D array of lenses **230** can be used as the 1D array of lenses **130** in the illumination device **102**. The 1D array of lenses **230** is formed (e.g., through injection molding) from a plastic material that is transparent to light emitted by the LEDs **125** of the illumination device **102**. The plastic material can be Poly(methyl methacrylate) (PMMA), for instance. In some implementations, the 1D array of lenses **230** also can include scattering centers (e.g., with diffraction indices different from the plastic material matrix) configured to effectively mix spectral components of the light propagating through the lenses. The 1D array of lenses **230** includes N lenses **230**(*j*), where j=1 . . . N. Here the number of lenses can match the number of LEDs **125** distributed on the substrate **120** of the illumination device **102**. The lenses of the 1D array of lenses **230** are separated from each other along the first direction (e.g., the x-axis) by a pitch L_X. In this example, a lens **230**(*j*) of the 1D array of lenses **230** is plano-concave. When the 1D array of lenses **230** is used in the illumination device **102**, the lens **230**(*j*) is arranged with the concave surface adjacent a corresponding LED **125**(*j*) and with the planar surface adjacent a corresponding light shield **140**(*j*). In some implementations, the lens **230**(*j*) is shaped such that the divergence θ of the light transmitted through the lens along the z-axis is less than 70°. For example, the lens **230**(*j*) is shaped such that the divergence θ of the light transmitted through the lens along the z-axis can be about 10°, 20°, 30°, 40°, 50° or 60°. In addition, in some cases, the shape of the lens **130**(*j*) can be such that an intensity distribution of the transmitted light is bat wing-shaped in polar coordinates.

[0025] In this example, the 1D array of lenses **230** further includes mounting elements **232**. A mounting element **232** includes one or more board mounting elements **234** to attach the 1D array of lenses **230** to the board **120** and to maintain alignment of the 1D array of lenses to the 1D array of LEDs **125**, for instance. Additionally, the mounting element **232** further includes one or more plate mounting elements **236** to attach the 1D array of lenses **230** to the mount **110**, for instance. Moreover, the 1D array of lenses **230** have multiple holes **238***h* used to mate and align the 1D array of lenses **230** to the 1D array of light shields **140**, for instance.

[0026] FIG. **3**A is a top perspective view, FIG. **3**B is a bottom perspective view and FIG. **3**C is a side view cross-section (e.g., in the x-z plane) of a 1D array of light shields **340**. In some implementations, the 1D array of light shields **340** can be used as the 1D array of light shields **140** in the illumination device **102**. The 1D array of light shields **340** is formed from a plastic material, e.g., PMMA. The 1D array of light shields **340** includes N light shields **340**(*j*), where j=1 . . . N. Here the number of light shields can match the number of lenses of the array of lenses **130** of the illumination device **102**. The 1D array of light shields **340** includes a pair of longitudinal side walls **342***x* extending along the x-axis, and (N+1) transverse side walls **342***y*(*j*), where j=1 . . . (N+1), extending along the y-axis, between the pair of longitudinal side walls. The transverse side walls **342***y*(*j*) are separated from each other along the first direction (e.g., the x-axis) by a pitch Lx. A side surface of a light shield **340**(*j*) is formed from a side surface **348***y*(*j*) of transverse side wall **342**(*j*), a side surface of **348***y*(*j*+1) of adjacent transverse side wall **342**(*j*+1) and portions of the longitudinal side walls **342***x* between the adjacent transverse side walls **342**(*j*), **342**(*j*+1). The light shield **340**(*j*) has an input aperture **344** with a dimension Di and an output aperture **346** with a dimension D_O larger than D_I. The input aperture **344** and the output aperture **346** are spaced apart by a separation H, and the side surface extends between the input and output apertures. Note that an optical axis **341** of the light shield **340**(*j*) passes through respective centers of the input aperture **344** and the output aperture **346** and is oriented, in this example, along the z-axis. FIG. **3**D is an end view cross-section (e.g., in the y-z plane) and FIG. **3**E is a diagonal view cross-section of the light shield **340**(*j*). Note that in this example, the input aperture **344** is circular and the output aperture **346** is square. As such, the dimension D'_O of the output aperture **344** in the diagonal cross-section is $D'_O=D_O*\text{sqrt}(2)$.

[0027] In order for light transmitted through lens **130**(*j*) and received at the input aperture **344** of the light shield **340**(*j*) to propagate through the light shield to the output aperture **346** without impinging onto the side surface **348***x*, **348***y*, a combination of the dimensions D_I, D_O and H of the light shield is configured to satisfy the following condition:

$$\tan\frac{\theta}{2} \le \frac{D_O - D_I}{2H},$$

where θ is a divergence angle of light transmitted through the lens along the z-axis. Note that the dimension of the output aperture is bound by the pitch along the x-axis, $D_O<Lx$. In the example illustrated in FIGS. **3**A-**3**E, the combination of the dimensions D_I, D_O and H of the light shield is configured such that each of the pair of side surfaces **348***x* and the pair of side surfaces **348***y* of the light shield **340**(*j*) form an angle of about 20° relative to each other.

[0028] In this example, the 1D array of light shields **340** further includes multiple pins **238***p* to mate, and maintain alignment of, the 1D array of light shields to the 1D array of lenses **130**. Here, the pins **238***p* of the 1D array of light shields **340** are to be mated with the holes **238***h* of the 1D array of lenses **230**.

[0029] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this technology belongs.

What is claimed is:

1. An illumination system comprising:

a substrate;

a one-dimensional (1D) array of light emitting diodes (LEDs) distributed on the substrate along a first direction;

a 1D array of lenses optically coupled in one-to-one correspondence with the 1D array of LEDs; and

a 1D array of light shields optically coupled in one-to-one correspondence with the 1D array of lenses, each light shield of the 1D array of light shields having an input aperture and an output aperture, the light shield comprising a lateral surface extending between the input aperture and the output aperture in a second direction substantially orthogonal to the first direction.

2. The illumination system of claim **1**, wherein

the output aperture is larger than the input aperture, and

the light shield is arranged with the input aperture adjacent to a corresponding lens of the 1D array of lenses.

3. The illumination system of claim **2**, wherein

the lateral surface of the light shield is a set of the lateral faces of a truncated pyramid, and

a contour of the base of the truncated pyramid forms the output aperture.

4. The illumination system of claim **3**, wherein the base of the pyramid is a rectangle.

5. The illumination system of claim **2**, wherein

the lateral surface of the light shield is the lateral surface of a truncated cone, and

a contour of the base of the truncated cone forms the output aperture.

6. The illumination system of claim **2**, wherein the light shield is configured in the following manner:

the input aperture has a dimension Di,

the output aperture has a dimension Do, and

the input aperture and the output aperture are separated by a distance H along the second direction that satisfies the condition

$$\tan\frac{\theta}{2} \le \frac{D_O - D_I}{2H},$$

where θ is a divergence angle of light transmitted through the lens along the second direction.

7. The illumination system of claim **6**, wherein the lens is shaped such that the divergence angle of the light transmitted through the lens along the second direction is less than 70°.

8. The illumination system of claim **1**, wherein the input aperture is circular.

9. The illumination system of claim **1**, wherein the 1D array of light shields comprises a plastic material.

10. The illumination system of claim **9**, wherein the plastic material comprises PMMA.

11. The illumination system of claim **1**, wherein a lens of the 1D array of lenses is a plano-concave lens.

12. The illumination system of claim **11**, wherein a surface of the lens adjacent to a corresponding LED is concave.

13. The illumination system of claim **1**, wherein the 1D array of lenses comprises a plastic material that is transparent to light emitted by the LEDs.

14. The illumination system of claim **13**, wherein the plastic material comprises PMMA.

15. The illumination system of claim **1**, wherein the 1D array of LEDs includes six or more LEDs separated by a distance of 0.5" between each other.

16. The illumination system of claim **1**, wherein the 1D array of lenses is mounted on the substrate and supports the 1D array of light shields.

17. The illumination system of claim **16**, further comprising

a housing; and

a mounting plate that supports the substrate, wherein the mounting plate is mounted inside the housing.

* * * * *